MICROSCOPIC PHOTOGRAPHY:

ITS ART AND MYSTERY.

THE PRINCIPLES OF THE ART DISCLOSED,

AND

ITS PRACTICE CLEARLY EXPLAINED.

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MICROSCOPIC PHOTOGRAPHY.

PRELIMINARY OBSERVATIONS.

THIS novel art is certainly one well calculated to attract the attention of all who are interested in Photography, whether professionally or as amateurs, whilst to the general public its results must appear little short of miraculous. By it, we are enabled to reproduce in a speck no larger than a letter of this type, a picture of Landseer's as beautiful as the original; a printed page as readable as the volume from which it taken; or a photograph of a giant cathedral wherein you may count every stone, and tell the hour by its great clock—nay, even a group from life, with the minutest feature of every individual discernible, and all brilliantly distinct under the higher powers of the microscope.

The few who have succeeded in the practice of an art which comes so much nearer to the minutiæ of nature's handiwork than anything hitherto known, have not been very communicative of the principles which govern it, and it may reasonably be supposed, that unless such a monopoly be broken through, this vast museum of curiosity and interest will remain only half explored.

To render, then, the practice of the art possible and easy to all whose desires tend that way, is the object of the present treatise. It is assumed, however, that the reader is not unacquainted with the ordinary practice of photography, and the instruments used in it, and will therefore perfectly understand the technical terms and allusions which must here be employed.

CHAPTER I.

ON THE REQUIREMENTS FOR OBTAINING THE DESIRED RESULT.

THE first thought of a photographer, on having his attention called to a microscopic picture, is almost necessarily that nothing can be more easy than to copy down to this proportion with a small lens by transmitted light, and by the ordinary photographic processes the beautiful negatives so readily obtained, and such is the fact.

It is essential, however, to understand that these minute micro-photographs are obtained by two distinct operations, viz.:—

When a suitable subject has been selected for the picture, a reduced negative copy of it must be first taken by the ordinary collodion process, (as directed in chap. 5), and this negative is then fixed at a suitable distance from the small lens and camera which is to produce the copy. The picture is then further reduced to the microscopic size, by the light transmitted through it reaching the copying lens, and giving an image on the collodionised plate, which is placed in the camera in the ordinary way of making photographs; and the copy, of course, being from a negative, would itself be a positive picture when viewed by transmitted light—thus far, all appears clear and simple.

But many conditions, both optical and chemical, of which the reader may not at the outset be in the slightest degree aware, have first to be fulfilled.

The first difficulty will be the character of lens required; and to this subject a short chapter is devoted in the following pages.

Next will arise some doubts as to the size of the negative to be used: the reply to which is, that it may be of any size from a half-plate to a half-inch one, and will entirely depend upon the instrument and means employed for copying it, of which it will be found there are some possible variations; and since all may not be equally effective, it is hoped that the reasons for this, amongst other things, will, in the course of this treatise, become intelligible to the reader.

However, let it here be observed, that in *all* cases the negative is the difficulty; copying, when once the needful instrument is well adjusted, is easy enough.

Yet another doubt will obtrude upon the uninitiated—the material upon which the picture is impressed—can it be only collodion? it is, and simply such as can be procured from a number of makers.

CHAPTER II.

THE LENS AND ITS COMBINATIONS.

PREMISING *with regard to illumination* that the best of all lights is that by which an ordinary portrait is taken, not only in its operative intensity, but in the manner of its supply and distribution, making every object on which it falls a *radiant* that cannot fail to define in the focus of a good instrument, it follows that if the operator possesses a lens which will give of microscopic proportions, a *negative* copy of any moderate sized print, or large photograph, in the ordinary way of "making" negative pictures, and such negative "stands" microscopic power to his entire satisfaction, it is the fairest test to which the lens can be put, and is surely all that can possibly be required of it.

An achromatic "inch-power" may reasonably be expected to do it, and, if by one of the best makers, it certainly will; but it is not desirable to have the lens of shorter focal length than one inch for two reasons; first, because a lens of half-an inch focus will not give even so small a "field" as the micro-speck entirely "flat"; secondly, that from the very nature of the surfaces produced by grinding and polishing lenses of very short curves, and which come to a *focus so closely to themselves*, they are liable, in addition to the image, to print upon the collodion film a pattern of their own imperfections, ranging from rings and striæ, to a network of light and shade proceeding from the mountain tops and darkened vales, of which the best polished surface microscopically consists.

The "structure of the collodion" of which we have heard so much, indicates that operators have met with this effect without tracing it to its true cause; for is it not clear that so perfect a non-crystallizable solution as collodion, can have no more structure than the glass upon which is poured? Admitted nevertheless, that the silver deposit which forms the image must possess a structure more or less granular, which a high power can dissect, and the greater or less delicacy of this kind of structure will vary much with the manipulation.

The achromatic inch-power may be called, therefore,

Lens No. 1, as perhaps the best procurable in the market at present. It must be mounted in a brass tube to screw into the flange attached to the camera, with a fine screw adjustment for focussing; it should also have a series of divisions engraved on the tube to estimate the allowance which will have to be made after the

focus is obtained, for the actinic and visual foci do not agree in these lenses, as will be explained in the chapter on Manipulation.

It is not intended to be implied that scientific opticians could not furnish a better form to be used as a camera lens, or that they will not do so when the requirements of microscopic photography become known.

But it being desirable that the ingenious operator should be enabled to test microscopic photography with such means as are probably already at his command, the two following formula are given for the construction of very efficient lenses for the purpose.

No. 2. Procure a well worked and centred plano-convex lens of two inches focal length (a thing of little cost), and the back glasses of a locket or quarter-plate portrait lens; combine these with the aid of a piece of brass tubing, so as to form with them an arrangement similar to that of the regular portrait lenses, putting the small plano-convex lens in the front, with its convex surface outside or next to the negative picture it is designed to copy. The distance between the lenses should be about $\frac{5}{8}$ of an inch.

No. 3. Should this be inconvenient, combine the plano lens as above, and still as the front lens with any single achromatic of 8 or even 12 inches focal length, putting the two flat surfaces next each other as directed for No. 2.

Of course, these two latter combinations are of greater focal length than No. 1, and require that with them a smaller negative should be employed.

No. 1 must be stopped a little in advance of it to an aperture of 1-16 of an inch, or even to a mere pin hole, if the operating light at command will allow of it.

Nos. 2 and 3 should be stopped to an opening of 1-8 of an inch and fixed between the lenses.

The reader is advised not too hastily to discard such combinations as last mentioned, although but a step in the right direction. Mr. Sutton, a gentleman of well-known ability in optical science, has shewn that for flatting the largest possible field without distortion, no combination is better than that of *two* plano-convex lenses a few inches apart, and having a concave lens midway between them acting as a diapragm; but a lens for the microscopic camera is not required to flat a wide field, but simply to give the maximum of *convex* definition through a small space in the centre of its field, which such a combination as No. 3, does with what is of nearly equal importance—a considerable concentration of light.

The manner in which these lenses can be mounted, and the

fashioning of the small camera with its plate holder, to which they are to be attached, may safely be left to the ingenuity and discretion of the operator, one only observation being required, viz.: that whatever the arrangement, provision must be made for a very nice adjustment of focus, either by a fine rack and pinion, or some equally delicate screw movement, as the difference of being in focus and out of it is a mere line or half a turn of a very fine screw.* The adjustment can be made by a fine screw thread in the brass tube which contains the lens, admitting of its being moved in its flange through the space of half an inch, but yet a caution with regard to the construction of the plate-holder itself, viz.: that the micro-slip it is meant to contain should in nowise come in contact on its prepared surface and upper and lower edges with any woodwork, but should be supported and kept from such contact by silver pins.

A small camera and lens can be obtained from most manufacturers of photographic apparatus properly adjusted at a cost of about 70s., including the lens and fittings.

This miniature camera must be attached to one end of a square wooden tube, the other end of the tube being occupied by a rabbet frame to hold the negative to be copied, *fig.* 1. No *dimensions* are given here to guide the operator in forming this simple instrument, for reasons which will appear subsequently.

Obviously, if the instrument is intended to be of small proportions, it might consist of brass tubing sliding in the telescopic form, with tightening screws and other convenient adjustments; but it may be desired, in experimenting to observe the path of the rays transmitted through the negative, a lid to the wooden tube is convenient for that purpose.

*This observation applies with equal force to any attempt which may be made to produce microscopic definition with lenses of much greater focal length.

CHAPTER III.

METHODS OF EMPLOYING THE INSTRUMENT.

BY OPEN DAYLIGHT.

All the methods that can be devised depend entirely upon the mode of illuminating the negative, and is by far the most important point to be considered in the whole process. A copying lens that will define has been shown to be easy of procurement, and a field, of half an inch at least, will be visible upon the ground glass under a magnifyer; now by viewing the picture produced under sufficient power, observing the difference between the definition of the margin, and the centre of such field, the operator will be enabled to focus exactly for that CENTRAL portion of the field, which is all that is required to be used.

The small camera at one end of the tube being in focus for the negative picture parallel with it at the other end, it might be supposed that nothing more was requisite than to slightly elevate the instrument to the sky, and copy by the light transmitted through the negative, which would thus impression very rapidly; but note the defect—the far distant sky which produces the impression is *not* in focus, though the negative picture at a short fixed distance is so. The operator would naturally adjust and readjust the instrument to obtain a better focus, and would succeed to a certain extent by a focal compromise between the two distances; a picture of course would be obtained, and look passably well under low power, but under a higher power, it would at once be seen to possess no true definition. The negative in this case is not, except in a partial degree, the "radiant," a term that was used (advisedly) before.

And yet by this method, with only a trifling addition to the instrument, very good results can be obtained; we will, therefore, call it, as being at once simple and available at most seasons of the year,

The First Method.

The addition consists simply in stopping—not the copying lens, for that is stopped already—but the negative picture at the other end by prolonging the wooden tube with an extension piece removable at pleasure to a few inches beyond the negative, so as to cut off from it all but that angle of the sky which it subtends with the copying lens.

There will still, however, exist, in a modified degeee, the radical

defect before mentioned, but the improvement is vastly greater than might have been anticipated.

Of course, there is a considerable loss of light, and the impression is produced less rapidly.

This loss of light is a great obstacle in the practice of micro-photography, otherwise it is easy to render copying by ordinary daylight a perfect process.

The Second Method.

It consists of bringing to *focus* upon the negative with a good camera lens (the larger the better) either the radiance of the open sky, or the reflected light from a whitened screen strongly illuminated, which being thus concentrated upon it in focal points, that passing through again diverge little or no light reaches the copying lens, but that which is diverted or *radiated* by the negative picture itself, which, therefore, as a "radiant" defines at its own proper focal distance. *fig.* 2.

For this method a small negative only can be used, somewhat less than the diameter of the opening of the illuminating lens; the precise dimensions of the negative will, therefore, depend upon those of the camera lens which can be employed as the illuminator.

The size of negative adapted to this method it may be as well to mention here, is likewise the one best adapted for copying by an artificial light, of which, probably, the reader may have heard so much at to lead him to wonder that it has not the preference over every other means. It will be noticed in its turn, observing in this place, that it is not more *rapid* or more efficient than the method just described; and that with so much excellent daylight ever running to waste, it seems a pity to burn the "midnight oil," or let off any kind of fireworks for the purposes of photography.

For merely experimenting, perhaps the most convenient way of adapting the small instrument to this method, is to affix it, tube and all, to one end of a short plank, and a large camera having a good lens, to the other end, in such a manner as to be perfectly in line with the copying instrument.

It should be used in a darkened room, a sufficient opening being made in the blind or shutter to admit the illuminating lens to a view of the sky, which can be focussed to the place of the negative by removing the latter from its rebate frame, and substituting a card upon which any distant object or a passing cloud may be sharply brought to focus.

It may possibly strike the reader that such a combination of in-

struments can be made to copy much larger negatives, as in truth it can, and will therefore constitute

The Third Method.

And requires that the camera at the end of the plank as described above, and which carried the illuminating lens, should itself be prolonged into another copying tube, and receive at its extremity in a rebate or frame, the large size negative intended to be copied, exposed to the full light of the sky, through an aperture in the darkened room as before. That which was the illuminating lens is now a copying lens; and forms in *air*, at the focal distance a reduced copy of the negative, which by a little management of the distances, can be made to fall in the *place* of the small negative (as its substitute.) at the end of the micro copying instrument The primary image of the negative need not however, if sufficiently small, fall more than 3 or 4 inches from the lens of the micro camera, which in that case, would require to be re-adjusted to the altered focal distance. From a contemplation of this arrangement (shown in *fig.* 3) it will be seen that it is the principle of the telescope adapted to photographic purposes, and is chiefly useful when the negatives are extremely large, and which can be reduced to the microscope with a good effect, nothwithstanding that what has been called the primary image of the negative, has in it all the defects of illumination pointed out in the first method.

BY SUNSHINE.

All other methods are a mere refuge when this, which *is* the true one, cannot be employed.

Illuminating the Negative by Direct Sunshine.

It is the most perfect of all, as giving at once operative intensity with the requisite defining power.

It is the most simple, as requiring only the primitive instrument, a tube with the copying camera at one end, and the negative picture at the other.

The negative can be of considerable size, (limited only by the defining field of the camera lens with which it is taken) the copying tube of any reasonable length, but not exceeding 5 feet, for the largest negative that can be employed with any advantage, while if a small negative be chosen, it need not exceed 18 inches.

For this method the darkened room in which it is at once requisite and convenient to operate, should have a southern or south-western aspect, with an opening in the shutter or blind capable of being closed at pleasure, and sufficiently large to admit a beam of sunlight that will cover the negative employed.

The solar rays may fall upon the picture in any oblique direction, at any angle passing through it and bearing away with them a bright but vague cast shadow of the image in any direction downward or sidelong, such rays not being required or desired to reach the copying lens. Here the negative becomes a true "radiant," and is copied only through the medium of those rays which are diffused by itself and which suffice to impression pretty rapidly.

The copying tube in this case being strongly illumined by the cast shadow image, it is advisable to stop it at intervals through its entire length with partitions having graduated openings, forming in a manner successive chambers in which all diffused light is lost and hindered from reaching the copying lens (see *fig.* 1); these stops, however, need not be more than three in number.

By Reflected Sunshine.

Any addition of reflectors to the instrument for the purpose of copying by sunlight or by daylight, is not only superfluous, but detrimental. It is requisite, however, not to overlook the possibility of their use.

A piece of good silvered plate framed and mounted in the manner of an ordinary swing looking-glass, should be attached with its stand turning on a pivot, and capable of being fixed in position, by a screw and nut to the negative end of the instrument. This small mirror requires to be much longer vertically than it is broad, and to be so fixed that the axis on which it turns is midway of the negative picture, or in other words, level with the axis of the copying lens; it will thus have a movement in two directions, and enable the operator whenever the sun shines upon it, to direct the "Jack o'lantern" through the negative picture straight along the tube, to reach the copying lens, when it will impression very rapidly.

The apparatus is one which has been used where a small picture is required to be greatly magnified, or where all the light possible to be obtained is absolutely necessary to the process; and for the same reason, it is probably the only means by which a very small negative could be further reduced to microscopic size by a lens of very long focus.

But observe that the focal distance for the nearly parallel rays of

the sun proceeding from the reflector, is not that of the negative picture, and the process is a mere copying of that vague cast shadow before directed to be utterly thrown away.

It is copying in an image of the sun that is considerably out of focus, and a defect precisely similar to that pointed out in the first day-light method.

BY ARTIFICIAL LIGHT.

There remains but this one other mode of illumination to be described. Many operators may have a prediliction for it as a winter evening's amusement.

It is accomplished by applying to the negative picture at the end of the instrument, and close to it a bull's eye lens (a half globe), the plano side towards the negative, and placing a lamp flame or moveable gas jet behind such lens at its focal diistance, which is twice the extent of its diameter. A concave reflector placed immediately behind the lamp flame is a great addition, as affording more light, of which very necessary influence it will be found there is not any too much.

To obviate this difficulty (deficient light) it is essential that the bull's eye or illuminating lens should be comparatively a small one, or, in other words, of short focal length, that the lamp flame may not be too far removed from it to operate intensely. The diameter of the bull's eye, too, determines the size of the negative, and consequently the length of the copying tube, and the shorter this may be the less is the distance from the lamp flame which is to produce the impression.

The arrangement affords a very good result if the negative be exceedingly fine, and the picture can be sufficiently impressioned; for although here again the negative is not the radiant, that position being held by the bull's eye behind it, yet the difference between their respective distances from the copying lens is not very great, and therefore not very material.

In strict theory, to perfect this process the negative picture should be taken on the plano side of the bull's eye itself, and illuminated by either the oxy-hydrogen and lime, or the electric light, to insure intensity and rapidity of impressioning.

CHAPTER IV.

ON SOME MATTERS OF CHOICE IN THE INSTRUMENT AND ITS USE.

It may at once be assumed that the operator's choice in these matters will greatly depend upon the means already at his command. If he has nothing larger than a quarter plate lens with which to "make" his negatives, that will necessitate a small instrument a copying tube from 12 to 18 inches long, and a negative not exceeding one inch in its largest dimension.

This may appear but a very small field for such a lens to cover, but it must be observed, that a negative for micro-copying should itself bear microscopic power in an eminent degree; and one of the first discoveries made by examining negatives under power will be, that the field of absolute definition in any lens is so very small indeed, that it will subtend with the object copied but a very slight angle not exceeding 8 or 10 degrees, where a perfect equality of light, and absolute definition are essential to the picture.

This absolute focal definition will not, in every lens. be found by merely looking for it on the ground glass; there is usually a better operating focus to be obtained than that which the eye can thus perceive, and which must be felt for experimentally with the sensitive plate.

If a larger negative be required, a lens of greater focal length must be used, that it may still subtend with the object to be copied the same small angle.

An instrument similar to *fig.* 1, fitted with lens No. 1 brought to absolute focus for the place of the negative at the other end, and then so fixed that it cannot shift, is ready for use at any moment, and can be employed by either of the daylight methods, 1 and 2, by that, which it is as well to reiterate, is the best of all (direct sunshine), and which, indeed, if sunshine in our climate were not nearly so scarce as cucumbers at Spitsbergen, would be the only method at all worth the attention of the operator, and likewise by the method with artificial light, the same small negatives being adapted to them all.

Theoretically, however, it may appear that the negative should actually be of the size to which the copy is designed to be apparently magnified, and that the microscopic pictures cannot be expected to bear power much beyond that point; this, with some limitation, is undoubtedly a fact.

(The limitation is, that much depends undoubtedly upon the excellence of the negative.)

If this view be entertained, and the copies intended to be greatly magnified, recourse must be had to a longer and larger copying tube.

If a whole plate lens be employed for making the negative, its field of acute definition will probably extend to 3 inches.

The copying tube required for this size picture, if fitted with lens No. 1, will not much exceed 4 feet in length, and is therefore sufficiently manageable, and if the lens be brought to absolute focus for the place of the negative and fixed there, the instrument will always be ready for use in direct sunshine.

I recommend, however, for general purposes that the negative be taken about two inches square, and for this size a half-plate lens will be required; this ought to give a picture of those dimensions, sharp and microscopically distinct; the copying tube then will be about thirty inches to three feet long, using a lens No. 1.

It is advisable both in the smaller and larger instrument that the tube should be made with a double body, as affording an additional means of placing the negative in exact focus, and of experimenting upon that point without altering the arrangement of the lens.

The observations heretofore made on the negative, apply equally to the larger as to the smaller size.

CHAPTER V.

ON THE CONDITIONS REQUIRED IN THE NEGATIVE, AND SOME METHODS OF OBTAINING THEM.

A high degree of definition as the first condition has been insisted upon before, and some optical means of obtaining it pointed out. For a further means to this end it should be remarked, that when engravings are to be copied, they cannot well be too large, and that pure line engravings are less suitable than those in the modern "mixed" style, which are finished in mezzotint, and for this reason, that although every line of the graver should, and will show beautifully in the negative, and captivate the operator with its exquisite fineness, yet when such minute lines are reproduced in the microscopic copies, they are too minute to tell effectively for what

they really are, and only give an appearance of coarseness to the picture.

It is true, that so small a subject as a bank-note has been well reproduced, and that the smallest page of print can be, but yet it is difficult from such originals to fulfil in the negative another condition to be mentioned hereafter; and such objects as white marble tomb stones with comparatively large and intensely black lettering, and blotchy prints of large masses, and simple forms, have been greatly preferred. Such portions of print as the Creed and Lord's Prayer are not negatived direct from the Book of Common Prayer; they can be obtained of the size of posting bills from the shops which supply them for the walls of the National Schools.

The condition alluded to is, that the negative should possess great intensity, and consequently some detail, and yet be a clear and brilliant positive; and this more particularly applies when the negative is of the smaller size, or is illumined by *any* other method than that of direct sunshine.

The operative portion of this part of the process is similar to that employed in the ordinary copying of prints by photography; but as the greatest perfection is required in these negatives, the following hints may be acceptable:

The print to be copied should be hung perfectly vertical, and in such a position that the light may fall upon it in an oblique direction; it is not advisable to illuminate by direct sunshine, but a strong light is essential. Employ a portrait combination of lenses, and insert a small stop between the front and back glasses to secure a sharp definition, and it is advisable to continue the body of the camera beyond the lens to prevent any rays reaching it, except those that have been reflected from the print to be copied.

Perhaps the best mode of development by which to obtain these negatives is with the solution of iron used for positives, and after well washing the plate with water, only to further develope or rather intensify with the negative solution of pyro-gallic acid, to which a drop or two of bath silver has been added—a method well known to most operators. It has, however, a tendency to give a certain degree of coarseness to the deposit of silver, and experiment only can decide whether to prefer it to the ordinary way with the pyro-gallic acid solution alone.

The difficulty of obtaining suitable negatives is much lessened, indeed almost vanishes when the larger size is used, and intended to be copied only by direct sunshine.

In strictness the negative should not be finished by varnishing,

as the transmission of light through the film of varnish, *after* it has been diverted by the picture, cannot be otherwise than detrimental to the copy: the objection, however, can be waived if the operator has not sufficient confidence in his ability to preserve the negative from injury without such final protection.

CHAPTER VI.

THE COPIES.

Some few observations are necessary on the Chemicals best suited to the copies.

Foremost of all considerations come the requirements of the

COLLODION.

which are—that it should not be thick and spongy, but thin and hard, taking a smooth, almost vitreous surface, and yet that it should not crack, a defect to which it is exceedingly liable, but which is not a necessary concomitant.

It would be invidious to indicate a preference for the collodion of any particular maker where many are excellent. A good material can frequently be prepared by mixing many different samples together and filtering it repeatedly not through paper, but a tuft of cotton wool in the neck of a glass funnel.

This process of filtration in even a simple collodion is frequently a necessity, and should be unsparingly employed whenever the pictures show spots, whether black or white. The fault is almost invariably in the collodion.

For cracking of the film, which when it occurs is unmistakeable, the dark parts of the picture exhibiting a network of absolute fissures, there is no remedy but to reject the sample of collodion, and take another. The cracks in the material occur previous to bathing as well as subsequently, and no peculiarity of manipulation will hinder them from appearing if the material has once acquired this character.

Defects in collodion, however microscopic, can spring only from one or all of the following causes, which, in these days of cheap manufacture, are common enough.

An imperfect pyroxyline from a *poor* sample of cotton.

More frequently the fault is in the solvent—an impure ether prepared from "methylated" spirit.

Methylated spirit used in iodising.

Spirit of low quality,—and therefore containing an undue proportion of water, which (more particularly when methyl is likewise present,) is a certain cause of reticulation and consequent cracking.

But with pure chemicals, a good collodion can always be prepared in the following manner:—

Procure some chemically clean cotton wool, sulphuric acid, (oil of vitriol) and pure nitrate of potass; these are all required for the preparation of pyroxyline. The first step will be to thoroughly pulverise the nitre in a pestle and mortar, and then thoroughly dry it in an oven, after which it may require a second crushing to reduce those portions which have caked together in the act of drying.

The process should be conducted in some building where it is unimportant if the acid should get upset, as with the greatest care these things cannot be avoided; then place a common frying-pan filled with sand on the fire, which forms a very convenient sand-bath; now mix in a porcelain vessel (a common breakfast cup) the acids in the following proportions—

Sulphuric Acid	6 ounces
Water	1 ounce

Then add $3\frac{1}{2}$ ounces (avoirdupois) of the powdered nitre, stir it well up until it ceases to effervesce, and forms an even pasty mass free from lumps; this part of the operation takes some minutes, then put the cup on the sand-bath, and when the temperature of the contents is 150°, immerse 60 grains of cotton wool, which should be pulled out into small flat tufts, and thrown separately into the acids, pressing each one to the bottom of the vessel with a glass rod; allow the cotton to remain in this condition for ten minutes, then pour off the excess of acid, squeezing the cotton with the glass rod against the sides of the vessel, and immediately throw the whole into a large pan of water; wash it quickly, opening the ball of cotton with the hands to remove the acid from it; gather up the floating portions, and remove all to a clean vessel and give them a second washing, after which it should be left to soak for some hours in pan of water frequently changed, in order to remove the remaining trace of acid, which it is extremely difficult to do; it now only remains to dry the pyroxyline either by pinning it in small tufts to a line, or laying it on blotting-paper exposed to the rays of the sun.

The principal precautions to be observed are these—

The temperature of the acid must be maintained as near as 150° as

possible. Chemical thermometers are made with the tube extending beyond the scale, so that the bulb can be immersed in the solution.

Keep the cotton wool *covered* with the acid mixture whilst it is converting, or it will decompose and evolve red fumes: the same result will follow if the pyroxyline is not plunged into the washing water and well opened out immediately; for the act of plunging it into water raises the temperature very considerably.

It should be remembered that the manufacture of pyroxyline requires caution—the acids are highly corrosive and evolve noxious fumes, therefore it is expedient to conduct the operation in a room where they can readily escape up the chimney.

The pyroxyline, when thoroughly dry, may be preserved for use in close stoppered bottles.

The Collodion is prepared thus:

Pyroxyline	40 grains
Pure Sulphuric Ether	2½ ounces
Absolute Alcohol	2 ounces

When the pyroxyline is all dissolved, allow it to stand for a few days to settle, then pour off the clear portion for use. This formula may seem to have an excess of alcohol, but it diminishes the risk of the film cracking, which strong etherial collodion is apt to do.

The Iodising Solution.

Alcohol ·816	2 ounces
Iodide of Ammonium	12 grains
Iodide of Cadmium	16 ,,
Bromide of Ammonium	8 ,,

This solution will settle in a few hours, and then is ready for use. Two drachms of this iodizer should be added to six drachms of plain collodion; the collodion ought not to be used until after it has been iodized and stood some days, in fact when some weeks old it answers much better than when fresh mixed.

THE SILVER BATH.

Pure Nitrate of Silver	30 grains
Distilled Water	1 ounce

Mixed in the usual manner of preparing the bath, leaving it slightly acid with acetic acid.

DEVELOPING SOLUTION.

The copies are necessarily developed with a solution of iron, both for their color, which should be black, and their brilliancy, which should be unclouded.

A much stronger solution however, than that ordinary used for positives should be employed, and may be prepared as follows—

Make (in boiling water) a saturated solution of proto-sulphate of iron; add to it (when cold) its bulk of strong acetic acid.

Preserved in a stoppered bottle this solution will keep for any length of time. For actual use a portion should be diluted with its bulk of water, adding nothing else whatever.

To develope the micro picture, a very small quantity only need be poured upon the plate when the speck appears almost instantly, and should be as instantly well washed in water, and immersed in the

FIXING BATH,

Not of cyanide of potassium, but of a strong solution of hypo-sulphite of soda, and when the iodide of silver is removed, be well washed and set up on end to drain and *partially* dry, when it should be again flooded with water, and again drained, repeating this process several times in order to free the plate perfectly from the hypo-sulphite of soda, which would otherwise crystallise in the substance of the film. No process is more efficacious for this purpose than repeatedly washing and draining the plate, never, however, suffering it to become more than half-dry until it is finished.

The reason for preferring hypo-sulphite to cyanide as the fixing agent, is, that the the latter certainly softens the film, and causes a considerable diffusion of the picture, thereby lessening its definition and distinctness.

FOCUSSING AND MANIPULATION.

Presuming the operator has determined to work by direct sunshine, and has his negative ready prepared, and the chemicals in good order, the first thing that will engage his attention is focussing the small camera; the negative being fixed into its frame at the end of the tube as shown in *fig.* 1, and the whole pointed to the light as directed in Chapter III, proceed to focus the small lens in the usual manner; but when this has been done, the focus must be altered to compensate for the difference between the actinic foci and that observed on the ground glass, for which purpose the divisions on the fine adjustment screw are essential. It will be found that if the centre of the picture is focussed sharp, and a picture then taken, the margin of the photograph will be considerably sharper that the centre, now by altering the fine adjustment so as to take the lens further from the sensitive plate, the central portion, or that which only is required, will be brought into correct definition; if notice is then taken how many divisions the adjustment screw has made, we

shall always know the precise allowance to give for that particular distance of negative.

It should, however be here observed, that when once the focus has been correctly determined, the negative may be repeatedly changed without the necessity of correcting the focus, provided the distance of the negative from the copying camera is kept the same.

Whatever the size of the negative, it must be framed into the rabbet or carrier with brown paper gummed on to the *back* of the glass to stop all light from passing, except through the picture. If the picture be square or oblong, this can be done with the slips of the paper; if circular or oval, such circle or oval must be cut out of the paper either before or after it is applied to the back of the glass plate.

CHAPTER VII.

MOUNTING THE COPIES.

The operator will not need to be informed that the picture is covered with a small disc of thin glass sealed down upon it with a transparent medium.

The material employed is Canada balsam, which may be used simply as it comes from the color shop or the chemist, but is much more easy to work with after it has undergone some preparation.

The preparation consists of insipisating the balsam by driving off with the aid of heat, a fluid constituent, which retards its drying or hardening, and which, when wholly driven off, leaves a residue in the form of tough resin.

The insipisation, which can be conducted in a porcelain cup with the aid of a lamp flame, should not, however, be pushed too far, but just to a point when the residuum, if touched, will draw out into long guttering threads like molten glass. The heat must be a gentle one, or the balsam will acquire a yellow tinge.

The residuum, before being allowed to get quite cool, must be diluted or dissolved with a small quantity of pure spirit of turpentine, merely sufficient to restore the balsam to its original consistency; it can then be preserved in a wide mouthed bottle for use in the following manner:—

Heat a pointed iron wire resembling a brad-awl, over the lamp flame, and dip it to the depth of an inch or more in the prepared balsam; from this let fall a single drop of the varnish upon the small glass disc, and upon it instantly lay down the microscopic picture, and turn the slip over quickly to bring the disc uppermost; a little dexterity will insure the microscopic picture being evenly in the centre of the disc.

Gently heating the slip over the lamp flame for a few seconds completes the operation.

It is usual before mounting to clean away the collodion film to a small square piece having the picture in the middle of it, but this is not necessary, as after the disc is affixed, the slip can be soaked in water with impunity, and is then easily cleaned off.

CONCLUSION.

When all has been done that can be done with both negative and copy, it will be found that no microscopic picture that can be produced from a negative by any mode of transmitted light, at all equals a negative of microscopic proportions taken in the ordinary way direct from the object by the light which it reflects.

So greatly superior is this natural mode of illumination to every form of transmitted light, that photographs can be taken direct from nature, with a lens so small as to be only a quarter of an inch in focal length, and if it be stopped with the smallest clear aperture that can be pierced with the finest cambric needle in a strip of thin brass or tin foil, it will give through a considerable field a negative picture that will stand microscopic power to any extent.

Thus then it will be seen that the whole art and mystery of microscopic photography is within the recognised laws of optical science, and that to the skilled optician as heretofore, we must still be indebted for the power of unlimited definition.

These observations will lead the operator to regret that such minute negatives cannot be printed; and that he may not rest under any illusion upon that subject, the following reasons why they cannot be, are offered for his consideration.

Firstly,—the substance upon which the picture is taken, and the deposit of silver which forms it, though exquisitely fine, are on so small a scale of definition, that they are great confounders of *transmitted* light.

Secondly,—as in printing upon wet collodion there must be an appreciable interval between the negative and the sensitive plate, a considerable loss of definition arises from this cause.

Thirdly,—though it is not difficult now to prepare collodion plates that can be used dry, and therefore can be printed upon by close contact, and under pressure there will still be a loss of definition for the reason firstly mentioned, and a further loss from the following cause—

That the impression in a film used dry, is not developed upon the surface as is the case with wet collodion, but in the substance of the film, there has still been an imaginable interval between the negative and the *place* of the copy.

Finally, no film that can be used dry, is sufficiently clean to bear microscopic examination.

But in the Appendix will be found a method of copying from Paper Negatives, a " dodge " to the best of my knowledge never before described ; it is by far the simplest plan, but only suitable for copying prints of a small size.

APPENDIX.

ON CERTAIN SUBSIDIARY METHODS, AND PRACTICAL APPLICATIONS OF THE ART.

It will be deduced from some observations contained in the "Conclusion," in which the superiority of reflected over transmitted light is insisted upon, that if a print were not too large to be copied down to the microscopic size with the small camera at a moderate distance, and its lights and shadows were reversed in the manner of a negative, it would give, in the usual way of copying prints, a picture that would be positive under the microscope, and having the maximum of definition procurable.

Where it is desired to experiment upon copying small and delicate engravings by this method, the first thing to be done is to print in *the pressure frame* on some very fine and smooth surfaced paper a negative copy of the engraving designed to be used.

The difficulties and requirements of this method have now to be pointed out.

In the first place, comes the fact that engravings do not copy *intensely* in the pressure frame; the printing ink upon them being very thin, and stopping, therefore, very little light, they do not admit of being impressioned very deeply. On ordinary copying paper, albumen, or otherwise, they can rarely be impressioned to a sufficient depth; resort must therefore be had to a prepared paper, which can be developed, and the intensity consequently aggravated; but this can only take place on a paper which will bear considerable "forcing" in the development, and yet retain very clean white lights, at the same time giving a good black or brown color.

The two following formula, &c., of such paper will be seen to present some novel features, and be found to give good results.

Make a solution of the double iodide of silver and potassium thus:—

To a small quantity of weak solution of *pure* nitrate of silver in water, about 10 grains to the ounce, add (quickly, and by candle

light) its bulk of a stronger solution of iodide of potassium, 30 grains to the ounce.

A precipitate of iodide of silver is instantly formed.

Pour the whole on to a filter of paper in a glass funnel or porcelain rest, in order to obtain the precipitated iodide of silver, which must be well washed upon the filter with several waters, and while still wet, collected and dissolved in a saturated or nearly saturated solution of iodide of potassium.

The strength of this last solution may be greater or less at discretion, but cannot well be less than that of a saturated solution diluted with its bulk of water.

Whatever its strength, it must be saturated with the washed iodide of silver prepared as above, and will be seen to be saturated when, after a short deposition, a small portion of the iodide remains undissolved in the form of a white powder at the bottom of the liquid.

This small superabundance of iodide should then be filtered out, and the double solution of silver and iodide of potassium thus formed will keep for any length of time, and bear open daylight uninjured.

In selecting the paper to be prepared it is essential that it should be of fine texture and smooth surface, yet the preference must be given to that of English manufacture. The paper marked "Hollingsworth," "Turner, Chafford Mills," or "Whatman's," can be recommended, care being taken that it has undergone no (so called) photographic preparation in its manufacture.

However good the paper may be it must still be "sized," not only as a part of its chemical preparation, but also for the purpose of keeping the after deposit of iodide of silver well on the surface.

For this purpose no form of gelatine is better than a piece of Scotch glue dissolved in water, and the solution, which should be of the same degree of thinness as ordinary size, applied, while warm and fluid, to one side only of the paper, (previously marked) using for the purpose a flat camel's hair varnishing brush.

The sheet can then be pinned up by one corner to the wall, or on to a strained cord, and when dry, with a similar brush to the one used previously, and which should be mounted in quill or horn, not bound with tin as is commonly the case.

*Wet the *gelatinised* surface of the paper thoroughly but quickly,

*This portion of the manipulation need not be done in the dark room, ordinary daylight having no effect on the process.

with the double solution of iodide of silver and potassium, and *instantly* plunge the prepared sheet into clear water (not distilled). When it has remained under water for a few minutes, the prepared surface will assume a deep primrose color. The water should then be changed or the sheet removed to a fresh quantity in another dish for the space of ten minutes, and the water then again be changed; and after a space, the result will not be the worse if the water be changed again.

In the last washing water the prepared sheet must be suffered to remain for several hours, even if the process be gone through over night, until the next morning, when it can be hung up to drain and dry. It is no way sensitive to light, and will keep, but paper somewhat freshly prepared *is* the best. The *deep* primrose color which the paper at first assumed gradually in the course of the prolonged washing, pales out to a much lighter tint. This is no symptom of any loss of iodide of silver, but only of its being perfectly freed from its former combination, and in a fit state for use.

To sensitize this paper prepare a solution of silver as follows—

Nitrate of Silver	40 grains
(In merely sufficient water to dissolve it.)	
Glacial Acetic Acid (solid at 50°).....	Half an oz.

Add the small quantity of silver solution to the glacial acid, drop by drop, shaking them together, and set the mixture aside until the next day when a deposit of white needle shaped crystals of silver will be formed.

Decant off the superabundant acid to the last convenient drop, and dissolve the crystaline deposit of silver in

Water.....	4 oz.

With a little of this weak solution of acid nitrate of silver, and a tuft of cotton wool, wet the iodized surface of the paper thoroughly, and hang it up in the dark to dry; it is then ready for the pressure frame.

This prepared paper is highly sensitive, and the exposure must therefore be counted by seconds.

To develope the picture, take a saturated solution of gallic acid, to which has been added a little of the gelatine size previously used (but not in sufficient quantity to render the mixture perceptibly viscid), and an atom or two of loaf sugar: and with this mixture, and a tuft of cotton wool, wet the prepared side of the paper.

When the picture becomes faintly, but distinctly apparent, (and not till then) with a fresh tuft of cotton pass over it a little of the

sensitizing solution of acid nitrate of silver, and afterwards another wash of the gallic acid mixture, and so on alternately, until the picture attains a satisfactory degree of intensity.

If, on applying the first wash of gallic acid, the picture appears at once, it is over impressioned. If it assumes a red colour, and will not allow the development to be carried to a violet black without at all discolouring the white portions of the picture, it is over impressioned.

Fix with hypo-sulphite of soda, which must afterwards be well washed out.

A weak solution of cyanide of potassium, 2 or 3 grains to the oz., can be used for fixing, care being taken not to expose the picture to the action of the cyanide for too long a time before washing it out.

This process, it must be admitted, is exceedingly troublesome from the many refinements of manipulation practised, none of which, however, can be omitted without injury to the result.

It is valuable for many uses besides the one proposed.

It is the best possible negative *paper* in the camera, for which use it will keep, when sensitized, for many hours or even days.

It is the best material for a life-sized portrait by the process of magnifying from a smaller negative in the "Solar Camera."

Formula No. 2 is a more simple mode of preparation, and likewise of development.

Chloride of Sodium	10 grains
Water	16 ozs.

On this solution float the paper (previously sized as before directed) for a minute or two, and hang it up to drain and dry.

Sensitize with

Nitrate of Silver	60 grains
Water	1 oz.

By floating or brushing, using however, if the floating method be not employed, a tuft of cotton wool, which can be changed for each paper, and any filaments remaining on the surface be brushed off when it is dry.

Develope by floating on a saturated solution of gallic acid. The picture which requires to be more impressioned than that on the iodized paper should be fully developed in a few seconds, and become very intense—fix with hypo-sulphite of soda and wash well.

Paper prepared by this last method will not, in very warm weather, keep for any great length of time, and should, therefore, be used immediately after it is dried.

To copy by reflected light the paper negative so obtained, it should be cut down close to the margin of the picture and mounted on a sheet of blackened glass, which can be made by coating one side of the glass with the black varnish used for photographs.

This can be fixed upright at one end of a short plank 4 or 5 feet in length according to the size of the paper negative, and the small copying camera, with its inch focus lens set at the other end, well centred for the picture, and the arrangement be used in any light and in any position.

The plank, however, will be better if formed into a tube to within about a foot or more of the place of the negative, leaving thus an opening which admits light to the negative picture only at the non-reflective angle of 40 degrees. (See *diagram No.* 4.)

It is quite possible that this form of the instrument may become of great practical utility; for where writings, or pages, or columns of print are required to be reduced to the microscope; it is not necessary to make *any negative of them at all,* written or printed subjects being quite as good—indeed, more effective, when seen as bright letters on a dark ground, than *vice versa,* and their definition, as before stated, will be finer.

True, they are inverted in the negative manner, but then there are two sides to a piece of glass, on either of which the picture taken can be viewed; and, furthermore, it is not necessary that the copies should be taken on the micro-slip of glass; they can be made just as well on the glass discs, which are afterwards to be cemented down upon the slips.

Let the small glass disc be first cemented to the micro-slip over the spot which the picture would occupy in the camera slide.

This can be effected with an atom of white wax placed under the disc, laid upon the slip, and gently warmed till it flows evenly to the edges of the disc.

The disc being upon the slip, is clearly no impediment to its being coated and bathed, and placed in the camera in the regular way, and the picture when taken and finished will be upon the disc. A slight heat detaches this, and it is then ready to be cemented down upon another slip in the ordinary way—a process which reinverts the print or writing, as is required.

Making such copies on the discs instead of the slips, has this advantage, that as many as half a dozen of them can be cemented on to *one* slip of glass of the usual length.

Should microscopic photography ever be employed as has been suggested, in the transmission of dispatches, whether in cypher or

otherwise, the last described method will necessarily be the only one employed, as being at once the least troublesome, absolutely perfect, and available by the ordinary daylight at all seasons of the year—except, indeed, it may be in November, and on the immediate banks of the Thames.

Seeing, too, that the thin glass discs can be cemented down upon others of greater thickness, and thus safely be made to form the moulds of even waistcoat buttons, or simply varnished like a sixpenny portrait, be let six deep into the jewelled bracelets of patriotic Demoiselles, it is not improbable that the most reprehensible number of *Punch*, or the most suggestive leader of a *Times* may yet pass easily the best guarded barriers in Europe.

Not that it is desired that the harmless microscope should become a superior kind of "infernal machine." The missiles here indicated are not fatal, though deadly!

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